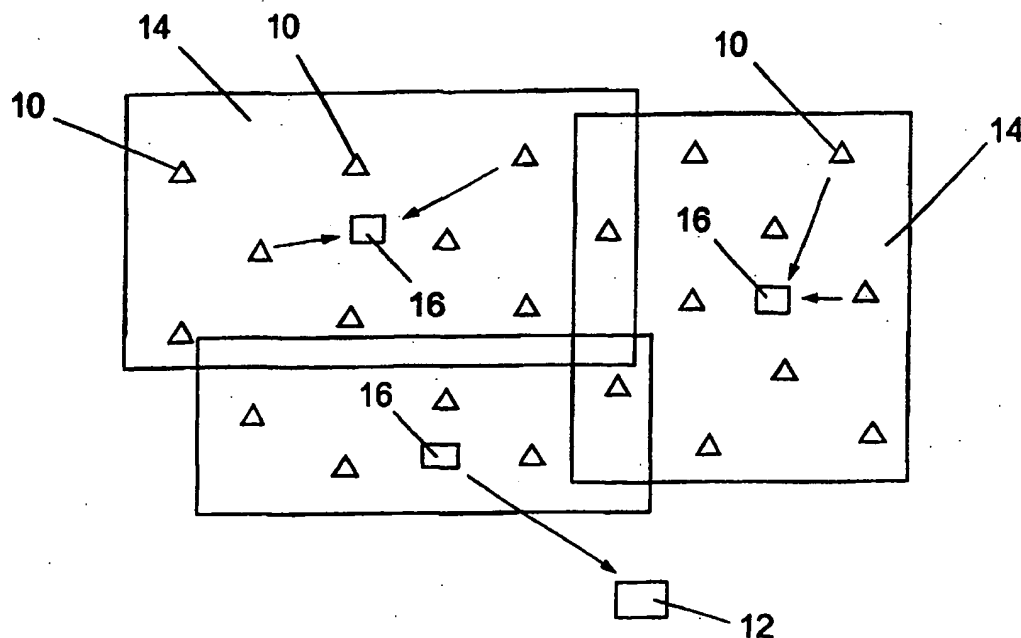




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(72) Inventors; and			
(75) Inventors/Applicants (for US only): PARK, William, Pentland [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). SMITH, John, Grant, Flavell [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). WHELAN, John, Christopher [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). HAMILTON, David, James [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). SANDHAM, William, Alexander [GB/GB]; Vibration Technology Limited, Scion			

(54) Title: SEISMIC ACQUISITION SYSTEM USING WIRELESS TELEMETRY



## (57) Abstract

A seismic acquisition system divides a survey terrain into a number of cells (14) each containing a cell access node (16) and a number of geophone units (10). The geophone units (10) transmit data in digital form to the respective cell access node (16) by wireless telemetry, and the cell access nodes (16) forward the data to a central control (12) by broadband channels.

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1       **SEISMIC ACQUISITION SYSTEM USING WIRELESS TELEMETRY**

2

3       This invention relates to seismic acquisition using  
4       geophones.

5

6       It is well known to conduct a geophysical survey of a  
7       land area by using an array of geophones in conjunction  
8       with either a succession of explosions or a continuous  
9       vibration applied to the ground by a vibratory  
10      apparatus.

11

12      Although the results obtained are valuable,  
13      conventional techniques are logistically slow, labour  
14      intensive, and costly. It is necessary to deploy a  
15      large number of geophones on a grid which has been  
16      previously surveyed. Each geophone string is  
17      individually wired to a central control unit. As the  
18      survey progresses, geophones in the rear must be  
19      disconnected, repositioned at the front, and  
20      reconnected. This procedure is extremely laborious,  
21      and the complexity of the connections gives a high  
22      probability of error. The scale of the problem will be  
23      understood when it is realised that a typical 3D  
24      seismic array involves up to 750 km of cabling.

25

1 An object of the present invention is to provide a  
2 means to simplify these procedures, and thus to reduce  
3 the time and cost of the survey by a significant  
4 factor.

5  
6 Accordingly, the invention from one aspect provides a  
7 seismic acquisition system comprising a multiplicity of  
8 geophone units which, in use, are arranged in an array  
9 across a survey terrain; each geophone unit comprising  
10 means for deriving digital data representative of  
11 seismic movement of the earth's surface at the geophone  
12 location, and wireless telemetry means adapted to  
13 receive command signals from a central control and to  
14 transmit said digital data to the central control on  
15 command.

16  
17 In a preferred form of the invention, the terrain is  
18 divided into a number of cells each of which contains a  
19 number of geophone units and a cell access node. The  
20 geophone units in a given cell communicate with the  
21 respective cell access node using wireless telemetry at  
22 a given frequency, with different frequencies used in  
23 adjacent cells.

24  
25 The cell access nodes may communicate with the central  
26 control by radio, or by cable or fibre optic link.

27  
28 The communication within each cell is preferably high  
29 frequency (most preferably 2.4 GHz band) low power.  
30 This permits a limited number of frequencies to be re-  
31 used across the terrain.

32  
33 The means for deriving said digital data may comprise  
34 an analog geophone measuring velocity, coupled to an  
35 analog-to-digital converter.

36

1 Each of the geophone units is preferably provided with  
2 a memory for short term storage of said data, and for  
3 permanent storage of a unique code identifying that  
4 geophone unit.

5  
6 Preferably, each of the geophone units has a  
7 preamplifier and preamplifier control means remotely  
8 operable from the central control. The preamplifier  
9 control means may be operable to control the gain  
10 and/or an operating time window of the preamplifier as  
11 a function of the distance of that geophone unit from  
12 the location of the seismic signal source being  
13 monitored, and/or as a function of time.

14  
15 Each of the geophone units may additionally have its  
16 unique code physically embodied internally or  
17 externally, or electronically tagged on a  
18 microprocessor forming part of the geophone unit, or as  
19 an external display for example in the form of a  
20 machine readable bar code, all of which can be read by  
21 wireless method using existing hardware.

22  
23 The wireless telemetry means is preferably digital, and  
24 may comprise a dedicated wireless system, or may be  
25 provided by a cellular wireless system.

26  
27 From another aspect, the invention provides a method of  
28 conducting a seismic survey in which a number of  
29 geophone units are positioned in an array across a  
30 terrain of interest, a seismic signal (or a series of  
31 seismic signals) is generated to produce seismic data  
32 collected by the geophone units, the data for each  
33 geophone unit is stored at the geophone unit, and said  
34 data is transferred to a central location using  
35 wireless telemetry, at the same time or at a later  
36 time.

1 An embodiment of the present invention will now be  
2 described, by way of example only, with reference to  
3 the drawings, in which:

4  
5 Fig. 1 is a schematic view of a seismic survey  
6 system;  
7 Fig. 2 is a block diagram illustrating one form of  
8 geophone unit for use in the system; and  
9 Fig. 3 is a schematic view of a survey area  
10 illustrating radio frequency allocation; and  
11 Fig. 4 is a block diagram of a central control  
12 used in the system.

13  
14 Referring to Fig. 1, a seismic survey across a  
15 "prospect" or area of terrain of interest is conducted  
16 by positioning a number of geophone units or remote  
17 acquisition units (RAUs) 10 at known locations,  
18 typically in a regular array. In the system of the  
19 present invention, each RAU 10 can receive signals from  
20 and transmit signals to a central control unit (CCU) 12  
21 using wireless telemetry.

22  
23 The array may be divided up into cells as indicated at  
24 14 each with a transmitter/receiver or cell access node  
25 (CAN) 16 acting as a relay between the RAUs 10 and the  
26 CCU 12. This division may be required by the nature of  
27 the terrain, but is advantageous in any event since it  
28 allows the use of low power in the RAUs 10, thus  
29 reducing size and cost.

30  
31 Fig. 2 illustrates an individual RAU 10 which may be  
32 used in the system of Fig. 1. The RAU 10 in Fig. 2  
33 uses a single conventional geophone or string(s) of  
34 geophones to provide velocity information at 20 in  
35 analogue form to an analogue to digital convertor 22  
36 via a preamplifier and filter stage 21. The digitised

1 information is stored at 24 for forwarding to the CAN  
2 16 via a transmitter/receiver 26 in accordance with  
3 control signals received from the CAN 16. These  
4 control signals and the forwarding of the digital  
5 information are by means of any suitable proprietary  
6 protocol.

7  
8 The RAU 10 also comprises a power supply 28 and control  
9 circuitry 30. The power supply 28 suitably comprises  
10 rechargeable or disposable batteries and preferably  
11 also a solar panel.

12  
13 Each of the RAUs 10 is identified by a unique code  
14 which may be stored in a dedicated area of the store 24  
15 as indicated at 24a.

16  
17 The control circuitry 30 controls operation of the  
18 preamplifier 21 in two ways.

19  
20 First, the gain of the preamplifier 21 is adjusted as a  
21 function of distance of the particular RAU 10 from the  
22 location of the seismic signal source; this provides  
23 more sensitivity at further distance from the source.  
24 This adjustment may suitably be made and changed as the  
25 location of the source is changed, the RAUs being  
26 stationary.

27  
28 Secondly, the gain may also be varied with time as the  
29 return from the seismic signal source decays, with more  
30 preamplification being used to boost the signal as it  
31 decays. For example, an RAU close to the seismic  
32 signal source could be set to have an initial gain of  
33  $2^0$  which is used for the first second of the signal and  
34 is increased to  $2^1$ ,  $2^2$  and  $2^3$  for each successive  
35 second, whereas a distant RAU may be set with an  
36 initial gain of  $2^4$ , increasing to  $2^5$ ,  $2^6$  and  $2^7$ .

1     These two factors are programmable from the CCU 12.

2

3     The control circuitry 30 also controls the operation of  
4     the digital wireless telemetry such that the power  
5     output is variable, allowing the number of RAUs 10  
6     reporting to any given CAN 16 and the distance of any  
7     RAU 10 from any given CAN 16 to be programmed, allowing  
8     the design of the seismic surveys to be flexible.

9     These factors are also programmable from the CCU 12.

10

11     In operation, the CCU 12 transmits a signal to  
12     indirectly activate the RAUs 10 prior to initiation of  
13     the seismic signal source and each unit then stores  
14     data for a given period after that signal. The CANs 16  
15     poll their respective RAUs 10 causing each RAU to  
16     transmit its stored information preceded by its  
17     identity code. By using different frequencies in the  
18     various cells 14, polling can proceed simultaneously in  
19     each cell, with the CANs 16 communicating with the CCU  
20     12 via a small number of broadband wireless links, or  
21     data cable or fibre optic links.

22

23     In a modification, RAUs may be used which each comprise  
24     two or more geophones operating with a single memory,  
25     control circuitry and transmitter/receiver.

26

27     The shape and size of the cells is determined by the  
28     range of the wireless transceiver, the terrain,  
29     obstructions, and to a lesser extent the weather. The  
30     RAUs in a given cell operate on one set of radio  
31     frequencies. Adjacent cells operate on different  
32     frequencies.

33

34     The telemetry system is able to re-use frequencies in  
35     non-adjacent cells. Fig. 3 illustrates this with  
36     reference to a survey area crossing a ridge (indicated

by contour lines 37). Given that the radio transceivers have a limited range, once outside that range a given frequency can be re-used in another cell. Thus radio frequencies can be re-used on a rolling basis to minimise the number of frequencies required by the system.

The radio system may particularly operate in the 2.4 GHz band at low power. High frequencies of this order decay quickly with increasing distance, which allows a limited number of frequencies to be used for an unlimited number of cells. The 2.4 GHz band is particularly preferred as this is a licence-free band in many territories.

In the event of a CAN receiving signals from a number of different cells, the system software can deduplicate the signals by deleting the weaker signals.

A suitable resolution will be obtained by each geophone generating 24-bit information at a repetition rate of 500 Hz (2ms sample rate). The bandwidth requirement of the polling system may be reduced by using known data compression techniques in the RAUs 10 or CANs 16.

As one example, for a 24-bit sample at 2ms intervals, the maximum data rate per geophone unit would be 12 kbits/s, and for a sector with eighty geophone units, the sector base station would have a maximum data rate of 1 Mbits/s. There are available low cost radiotelemetry modules suitable for this data rate; for example, the "Prism" radio chipset from Harris Semiconductor Limited can handle up to 4 Mbit/s.

Fig. 4 shows one suitable form of CCU. Data is

1 captured on a commercially available seismic  
2 acquisition recording unit 44 of known type. This  
3 issues timed shot commands at 46. Each shot command  
4 causes a sync pulse generator 48 to generate a sync  
5 pulse 1 to activate the geophones, and a series of  
6 timed sync pulses 2, to control the polling. The sync  
7 pulses are encoded and transmitted at 50 via a  
8 transmit/receive switch 52, which also gates incoming  
9 data signals to a receiver and decoder 54 to supply  
10 data for the recording unit 44.

11  
12 In a modification of the CCU, the sampling interval is  
13 reduced stepwise in time. As one example, instead of  
14 sampling every 2 ms for a total of 4s, the sampling  
15 rate would be every 2 ms for the first second, every 4  
16 ms for the next second, every 6 ms for the third  
17 second, and every 8 ms for the fourth second. The  
18 reason for this is that high frequency information is  
19 attenuated with time in comparison with low frequency  
20 information, and therefore the further one is away in  
21 time from the input event the less high frequency there  
22 is to be measured and the sampling rate can be reduced.

23  
24 It is of course necessary for the CCU 12 to have  
25 information defining the position of each of the RAUs  
26 10. This may be achieved, as is currently done with  
27 wired systems, by securing the RAUs 10 at positions  
28 previously marked by conventional surveying. To assist  
29 in loading information defining which RAU is at which  
30 location, each RAU may conveniently be provided with an  
31 external, machine-readable label such as a conventional  
32 bar code with that unit's unique identity code. The  
33 personnel installing the units can thereby enter the  
34 location number and the corresponding geophone code in  
35 a simple manner into portable recording apparatus for a  
36 subsequent downloading into the central control 12.

1 As an alternative, each RAU could include an electronic  
2 positioning means which would enable the RAUs to be  
3 positioned on the terrain without a preliminary survey  
4 with the position of each RAU thereafter being  
5 established by the CCU 12 by polling location data from  
6 the RAUs 10. Such electronic positioning means could  
7 be provided by a GPS system. Positional accuracy can  
8 be improved by use of Differential GPS (DGPS). Rather  
9 than incurring the expense of DGPS in each RAU, since  
10 the RAUs are at fixed locations the positional  
11 information can be loaded into the RAU when it is  
12 installed; conveniently this could be done by infra-  
13 red, radio or any other suitable means of short range  
14 data transfer linking from a portable DGPS apparatus  
15 which also includes the bar code reader.

16  
17 Alternatively, the position of the CAN for each cell  
18 could be fixed by a GPS receiver in the CAN, and the  
19 relative position of each RAU with respect to its CAN  
20 determined by a relatively simple local system.

21  
22 It is likely that a dedicated wireless telemetry system  
23 would require to be used, with one frequency to carry  
24 commands from the CCU 12 indirectly to the various RAUs  
25 10 and a number of separate frequencies to carry data  
26 in reverse. In certain locations however it might be  
27 possible to use systems similar to cellular telephones  
28 for both commands and data.

29  
30 Other modifications and improvements may be made to the  
31 foregoing within the scope of the present invention, as  
32 defined in the following claims.

33

CLAIMS

1. A seismic acquisition system comprising a multiplicity of geophone units arranged in an array across a survey terrain, wherein each of said geophone units comprises means for deriving digital data representative of seismic movement of the earth's surface at the geophone location, and wireless telemetry means adapted to receive command signals from a central control and to transmit said digital data to said central control on command.
2. A seismic acquisition system as claimed in Claim 1, wherein said survey terrain is divided into a number of cells, each of which contains a plurality of geophone units and a cell access node.
3. A seismic acquisition system as claimed in Claim 2, wherein said plurality of geophone units within a given cell communicate with said cell access node using said wireless telemetry at a given frequency, with different frequencies used in adjacent cells.
4. A seismic acquisition system as claimed in Claim 3, wherein said communication within each cell is high frequency (2.4 GHz band) low power.
5. A seismic acquisition system as claimed in Claim 3 or Claim 4, in which a given frequency is used in a number of non-adjacent cells across the terrain.
6. A seismic acquisition system as claimed in any of

1 Claims 2 to 5, wherein said cell access nodes  
2 communicate with said central control by radio, by  
3 cable, or by fibre optic link.

4

5 5. A seismic acquisition system as claimed in Claims  
6 3 and 4, wherein said communication within each  
7 cell is high frequency (2.4 GHz band) low power.

8

9 7. A seismic acquisition system as claimed in any  
10 preceding Claim, wherein said means for deriving  
11 digital data comprises an analog geophone  
12 measuring velocity, coupled to an analog-to-  
13 digital convertor.

14

15 8. A seismic acquisition system as claimed in any  
16 preceding Claim, wherein said geophone units are  
17 provided with a memory for short term storage of  
18 said data, and for permanent storage of a unique  
19 identification code.

20

21 9. A seismic acquisition system as claimed in any  
22 preceding Claim, wherein each of said geophone  
23 units has a preamplifier and preamplifier control  
24 means.

25

26 10. A seismic acquisition system as claimed in Claim  
27 9, wherein said preamplifier control means is  
28 operable to control the gain and/or an operating  
29 time window of said preamplifier as a function of  
30 the distance of said geophone unit from the  
31 location of the seismic signal source being  
32 monitored, and/or as a function of time.

33

34 11. A seismic acquisition system as claimed in Claim  
35 8, wherein each of said geophone units has its own  
36 unique code physically embodied internally or

1 externally, or electronically tagged on a  
2 microprocessor forming part of said geophone unit,  
3 or as an external display such as a bar code.  
4

5 12. A seismic acquisition system as claimed in any  
6 preceding Claim, wherein said wireless telemetry  
7 means is digital.  
8

9 13. A method of conducting a seismic survey, wherein a  
10 plurality of geophone units are positioned in an  
11 array across a terrain of interest, a series of  
12 seismic signals is generated to produce seismic  
13 data collected by said geophone units, the data  
14 for each of said geophone units is stored at said  
15 geophone unit, and said data is transferred to a  
16 central location using wireless telemetry, at the  
17 same time or at a later time.  
18

19 14. A method according to Claim 13, in which said  
20 survey terrain is divided into cells, each of  
21 which contains a plurality of geophone units and a  
22 cell access node, said data being transferred from  
23 each geophone unit to its respective cell access  
24 node by wireless telemetry, and from each cell  
25 access node to said central location by radio, by  
26 cable, or by fibre optic link.  
27

1 / 4

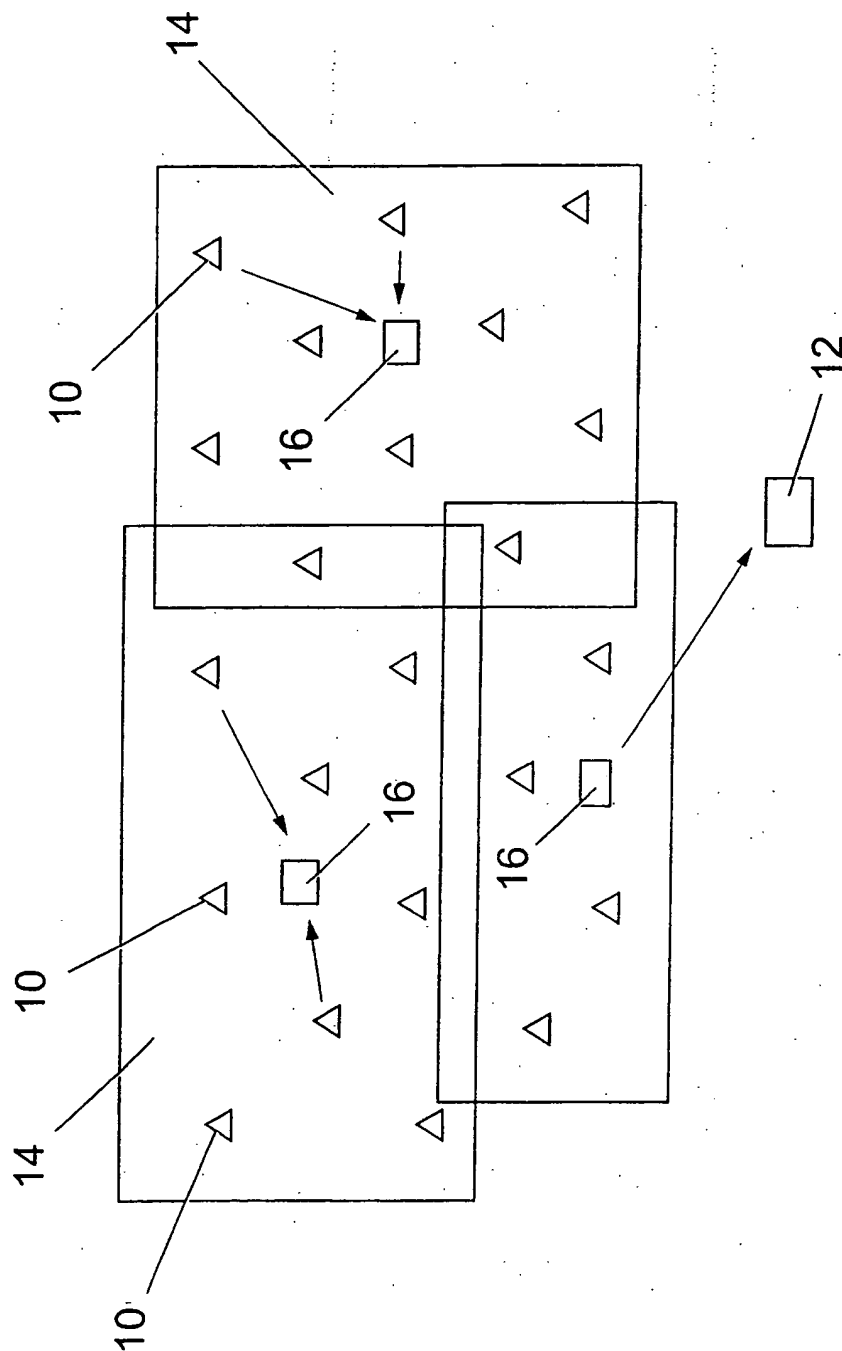


Fig. 1

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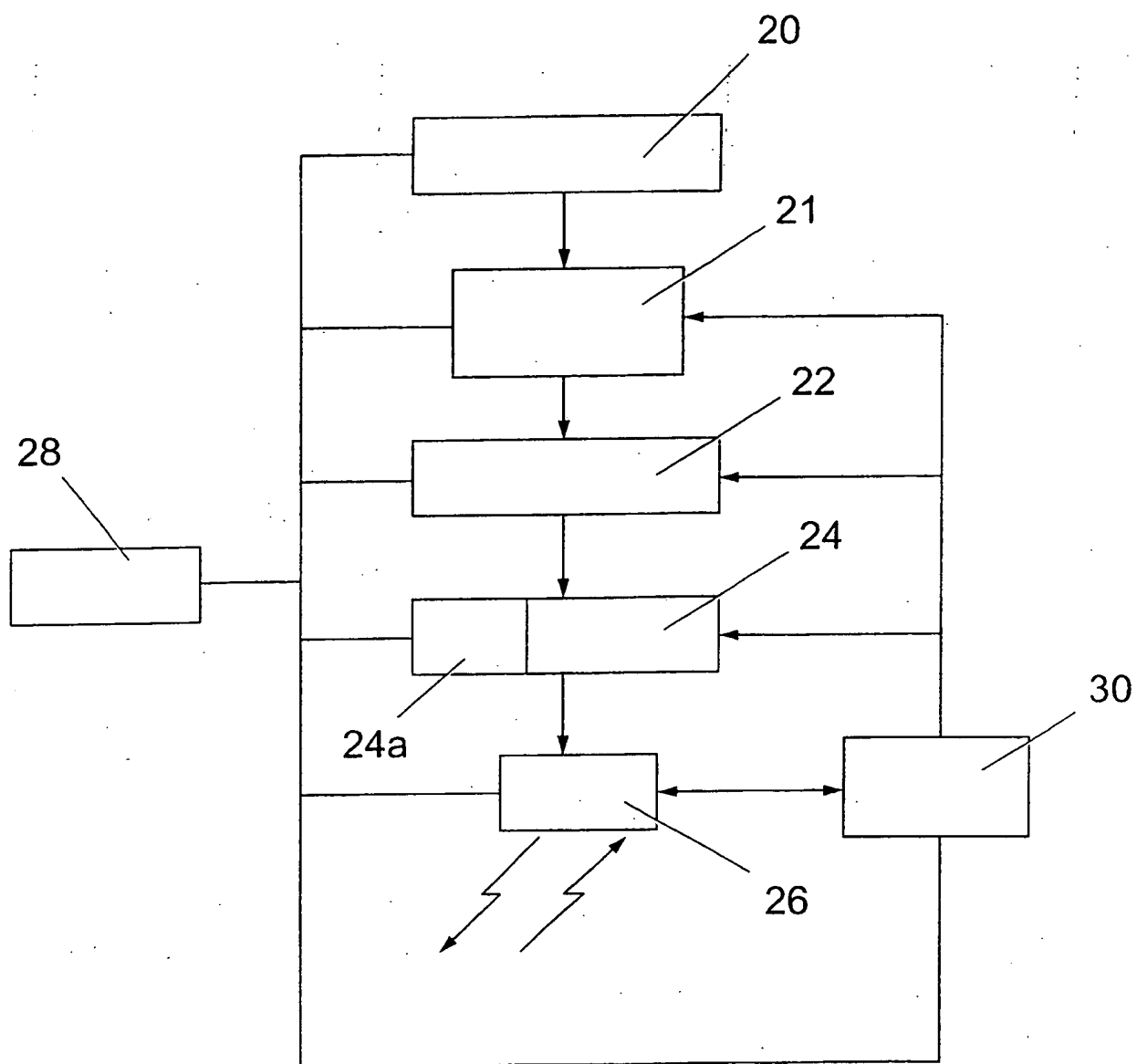


Fig. 2

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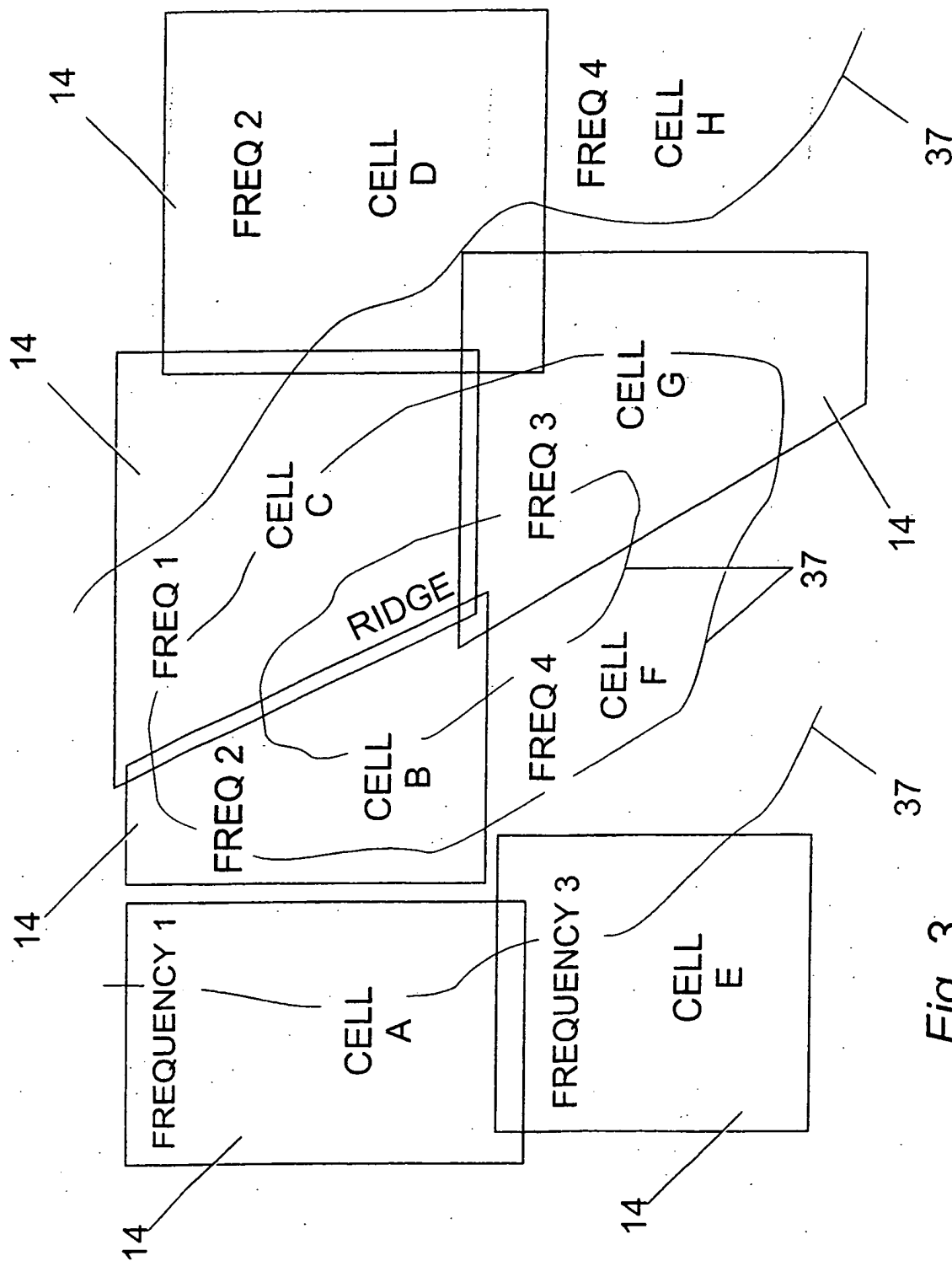
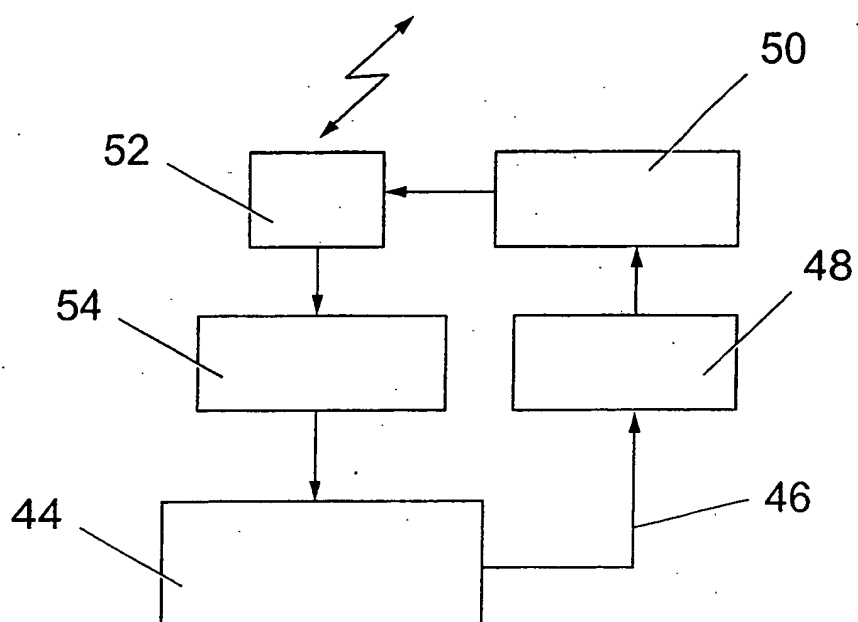


Fig. 3

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*Fig. 4*

# INTERNATIONAL SEARCH REPORT

Intel onal Application No

PCT/GB 97/02924

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G01V1/22

According to International Patent Classification(IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Date of the actual completion of the international search

20 February 1998

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,

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Anderson A

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